

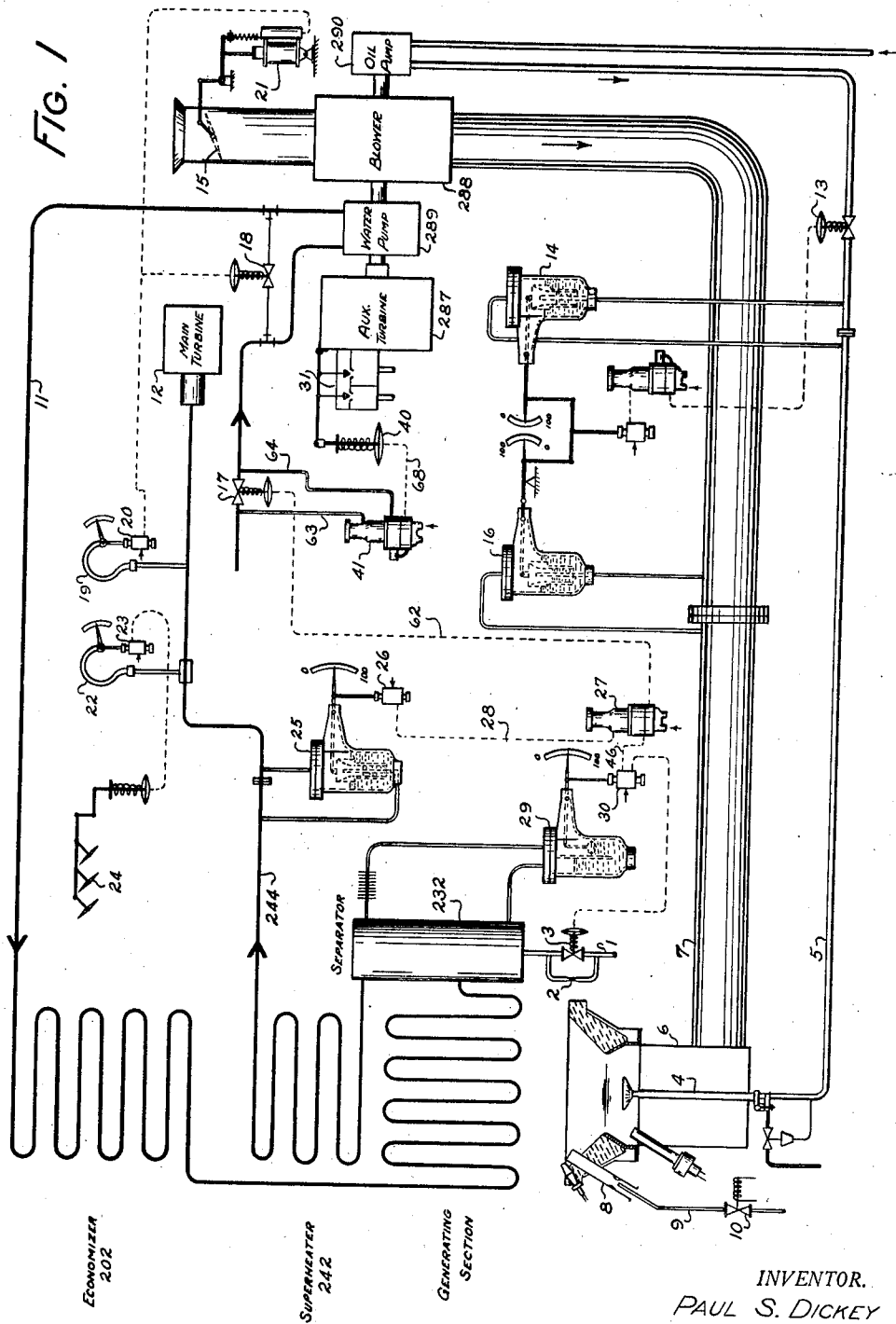
Aug. 22, 1939.

P. S. DICKEY

2,170,348

CONTROL SYSTEM

Original Filed Dec. 18, 1935 3 Sheets-Sheet 1



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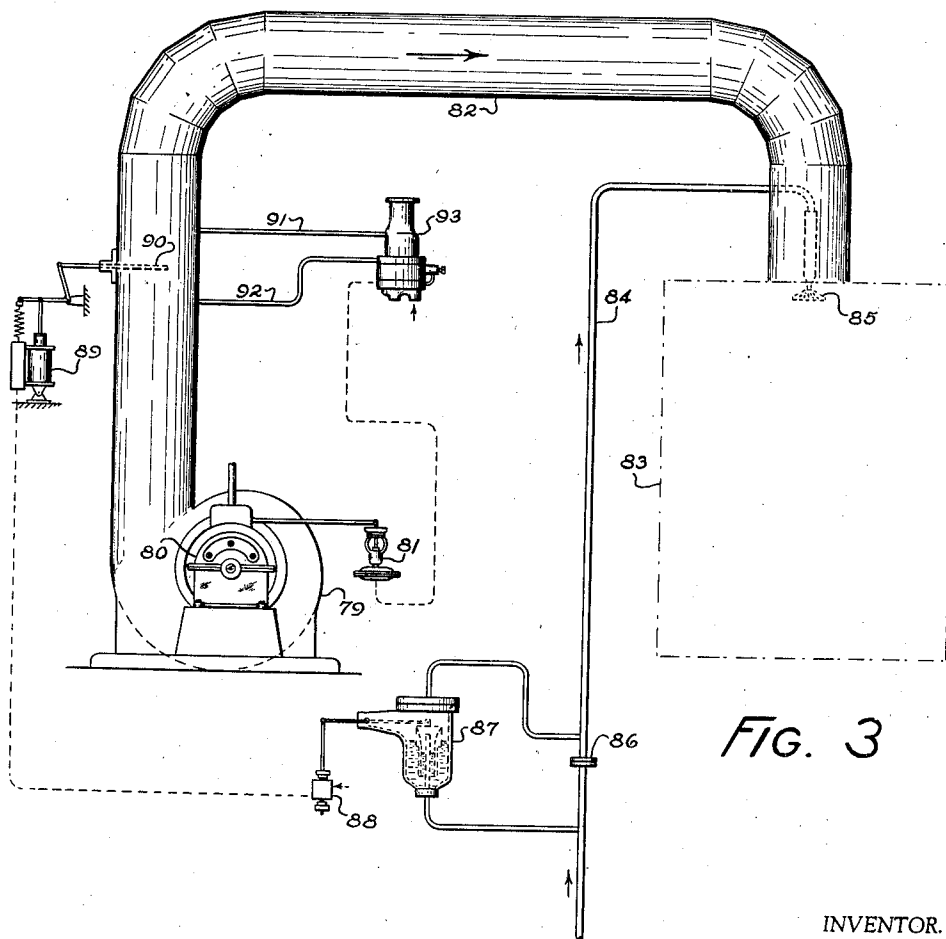
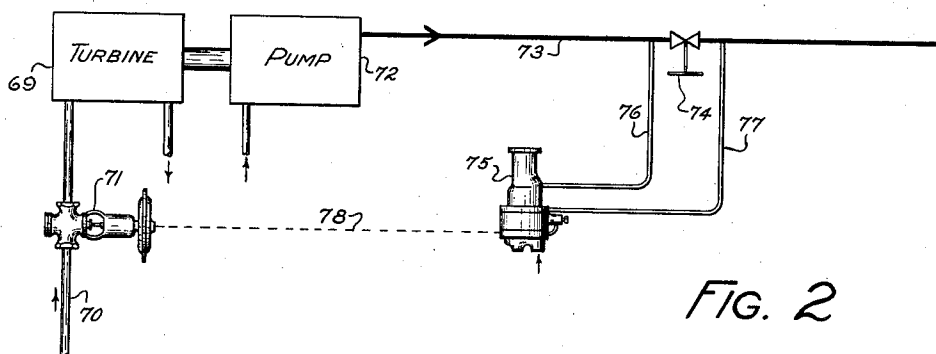
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CONTROL SYSTEM

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3 Sheets-Sheet 2



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CONTROL SYSTEM

Original Filed Dec. 18, 1935 3 Sheets-Sheet 3

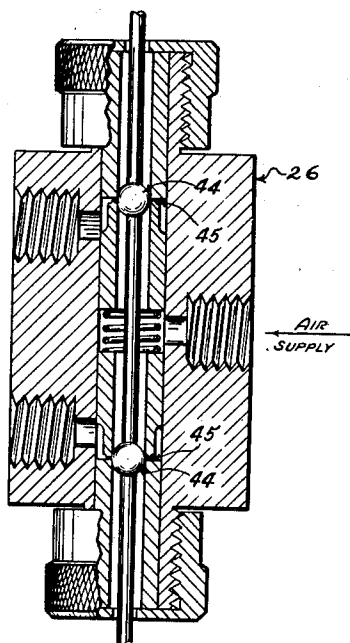


FIG. 4

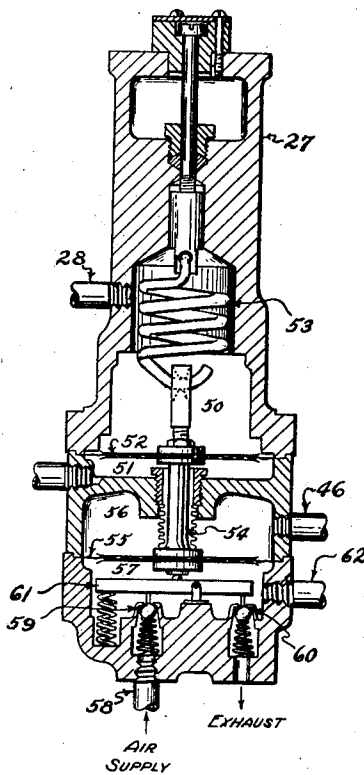


FIG. 5

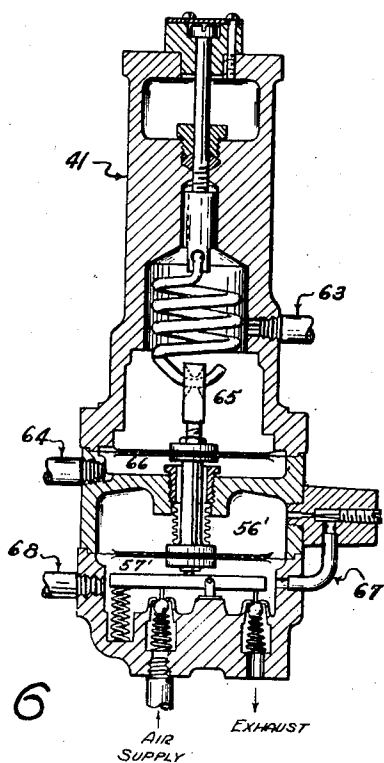


FIG. 6

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2,170,348

CONTROL SYSTEM

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Application December 18, 1935, Serial No. 55,026
Renewed November 25, 1938

9 Claims. (Cl. 122-448)

This invention relates to a method and means for operating and controlling the operation of speed-governed apparatus such, for example, as elastic fluid turbines; and in particular where such a turbine is driving a pump, fan, or similar machine, and where the speed of the turbine is desirably to be maintained in accordance with the value or relation of values of variables in the operation of the system.

To make clear the arrangement and functioning of my invention I have chosen to illustrate and describe it in connection with a power producing and utilizing system comprising in general a vapor generator, a vapor utilizer, and certain auxiliaries for supplying liquid and the elements of combustion to the vapor generator.

The particular vapor generator of the present embodiment is of the drumless, forced flow type, having a fluid flow path including one or more long small-bore tubes, in which the flow in the path is initiated by the entrance of liquid under pressure at one end, and the exit of vapor only at the other end; characterized by an inflow of liquid normally greater than the outflow of vapor, the difference being diverted from the path intermediate the ends thereof.

Such a vapor generator having small liquid storage and operated with wide range combustion devices forms a combination rendering practical extremely high heat release rates with the consequent ability to economically handle practically instantaneous load changes from minimum to maximum, and vice versa, without heavy standby expense, and is particularly suitable for operating conditions such as locomotive service, where load variations are of a wide range and are required to be met substantially instantaneously.

The generator has a minimum liquid storage capacity with a maximum heat absorbing surface so disposed and arranged as to be substantially instantaneously responsive to rapid changes and wide diversities in heat release rate in the furnace. The heat absorbing surface is arranged in relation to the path of the products of combustion and radiant heating so that the entering liquid is received at the cooler end of the path. Further, the vapor generator insofar as the passage of combustion gases is concerned has a continuously increasing resistance to gas flow throughout the length of the passage.

The heat absorbing surface, or flow path for the working medium, is comprised of one or more long small-bore tubes with an enlargement, preferably at the end of the generating section, which acts as a separator to divide liquid and

vapor. The vapor is then passed through a superheater, while the excess liquid carried through the tubes for the purpose of wetness and preventing scale deposit, is diverted out of the separator under regulated conditions, as will be hereinafter set forth. From the separator there is a normal continuous and an additional regulated spillover or diversion of a part of the liquid entering the economizer under pressure, so that there is always being fed to and through the economizer and vapor generating sections more liquid than can be converted into vapor in a single passage therethrough, although the proportion of such excess liquid represents but a small part of the total volume of fluid passing through the vapor generator and is at most times only sufficient to insure tube wetness and to carry off scale forming material.

In vapor generators of the character mentioned having small liquid and heat storage with high heat release capabilities, the liquid inflow must of necessity be continuous and at all times proportioned to the vapor outflow, at the same time taking into account the desired diversion of excess liquid from the flow path. Furthermore, to accomplish the wide range in heat release with substantially instantaneous response and to perform the combustion process efficiently, a method and means for operating such a vapor generator in accordance with varying conditions must be provided.

The present invention, while particularly illustrated and described in connection with the before mentioned type of drumless forced flow vapor generator, is by no means limited in its application to this type of vapor generator or in fact to vapor generators as a class. It is equally applicable as a method and apparatus in any system wherein the output of a governed machine is utilized as a function in the control of said machine.

A principal object of the invention is to provide a control sensitive to and responsive to the output of a governed machine and for controlling the speed of said machine.

A further object is to provide a control for a governed machine sensitive to the output of said machine as well as to other variables in the operation of the same or another system.

Another object is to so control the operation of a drumless forced flow vapor generator as to satisfactorily produce wide changes in heat release rate with great speed, through proper regulation of liquid inflow and of the elements of combustion:

Further objects will become evident from a study of the specification and of the drawings, in which:

Fig. 1 diagrammatically illustrates a drumless forced flow vapor generator, combined with the requisite apparatus to control the functioning thereof, and such apparatus shown in partially diagrammatic fashion.

Fig. 2 illustrates a second embodiment of the invention.

Fig. 3 illustrates a third embodiment of the invention.

Fig. 4 is a sectional elevation of a pilot valve.

Fig. 5 is a sectional elevation of a pneumatic relay.

Fig. 6 is similar to Fig. 5 but embodies certain additional features of construction.

In the various drawings, identical parts bear the same reference numerals.

The drumless forced flow vapor generator, in connection with which the present invention is to be described, is diagrammatically illustrated in Fig. 1 to indicate gas flow, working fluid flow, and heat absorbing surface. The flow path for the working medium is comprised of long small-bore tubes brought together at suitable headers. The generator includes an economizer 202 at the cooler end of the gas passage and which receives liquid from a pump connected to the hot well or other source (not shown).

The liquid from the economizer 202 is conveyed to one or more tubular fluid flow passages constituting the generating section of the assembly which comprises floor, wall, screen and roof portions of the furnace.

The flow circuits comprising the vapor generating surface enter a bulge in the fluid flow path which is in the form of a separating chamber 232 for dividing the fluid into liquid and vapor; the vapor passing to a superheater 242, and the excess liquid being diverted from the fluid flow path through a pipe 1 to the hot well or to waste. A normal continuous spillover occurs through the restriction 2 while a variable spillover occurs through the regulating valve 3.

The "heat source" includes an oil burner 4 supplied by a pipe 5 and an air chamber 6 supplied by a conduit 7. In order to provide for initial ignition of the oil-firing means, a gas-firing device 8 is supplied by a pipe 9 with flow of gas under the control of a solenoid actuated valve 10.

I illustrate the fluid flow path as a single sinuous tube, to the economizer section 202 of which, liquid is supplied under pressure through a pipe 11 from a pump 289, which while it is illustrated merely diagrammatically may be of any suitable type. From the economizer section the fluid passes to and through the generating section discharging into the separator 232. From the separator, vapor passes to and through the superheater 242, leaving by a conduit 244 to a main turbine 12 illustrative of a vapor consuming device. Products of combustion pass successively through the generating section, superheater, and economizer and may contact a part or all of the separator.

An auxiliary turbine 287 drives the liquid feed pump 289, an air blower 288, and a fuel supply pump 290. While I have illustrated these devices diagrammatically and as though all are located to be driven by the same shaft and at the same speed, it will be understood that the necessary gear reduction, or driving connections between the several devices, are known and would

be properly designed as to relative speed, power, etc., and that I merely intend to indicate that the auxiliary turbine 287 drives the devices 289, 288 and 290 simultaneously and in unison.

The rate of supply of fuel oil to the burner 4 is primarily controlled by the speed of the oil pump 290, but the supply of oil is further regulated by the throttling of a regulating valve 13 located in the pipe 5; and the rate of flow is continuously measured by a meter 14.

The rate of supply of air to support combustion is primarily determined by the speed of the blower 288, but is further under the control of a damper 15 positioned in the conduit 7 at the inlet to the blower. The rate of supply of air is continually measured by a flow meter 16.

The rate of supply of liquid under pressure through the conduit 11 is primarily controlled by the speed of the pump 289, but is further influenced through the positioning of a regulating valve 18 in a by-pass around the pump.

In the operation of such a vapor generator certain variables are measured, indicated, and utilized as the basis for automatically controlling the supply of liquid thereto and the supply of the elements of combustion to the heating furnace.

I indicate at 19 a Bourdon tube adapted to advise the instantaneous value of vapor outflow pressure and to position a pilot valve 20 for the control of the by-pass valve 18, and of a pneumatic actuator 21 for positioning the damper 15.

At 22 is indicated a Bourdon tube forming a part of a temperature sensitive system adapted to advise the instantaneous value of vapor outflow temperature and to position a pilot valve 23 for the control of superheat regulating dampers 24.

As an indicator of generator output, or load upon the vapor generator, I provide a flow meter 25 for advising the instantaneous value of the rate of vapor outflow from the superheater 242 and for positioning a pilot 26 to establish an air loading pressure at the relay 27 through the pipe 28.

29 represents means responsive to liquid level within the separator 232 and constitutes a pressure casing enclosing a mercury U-tube connected across the vertical elevation of the separator. A float is adapted to rise and fall with the surface of the mercury in one leg and to thus cause a positioning of exhibiting means of the instantaneous value of the liquid level within the separator, and simultaneously to position a pilot valve 30 to establish an air loading pressure representative of liquid level at the relay 27 and for the control of the valve 3.

The flow meter indicated in general at 14 for providing a measure of the rate of supply of fuel to the furnace is of a known type such as is disclosed in the patent to Ledoux, No. 1,064,748. Such a meter is a differential pressure responsive device adapted to correct for non-linear relation between differential pressure and rate of flow, to the end that angular positioning of its pointer relative to an index is by increments directly proportional to increments of rate of flow. I illustrate by dotted lines within the flow meter 14 the outline of the internal construction wherein is a liquid sealed bell having walls of material thickness and shaped as described and claimed in the above mentioned Ledoux patent.

The flow meters 16 and 25 are similar in construction and operation to the flow meter 14.

I preferably primarily control the supply of liq-

uid to the fluid flow path and the elements of combustion to the furnace, through variation in speed of the auxiliary turbine 287; utilizing the liquid inflow, vapor outflow, and level of liquid within the separator, as the basis for such control. Realizing however, the possible difference in characteristic of the pump and blower, as well as variations in conditions of operation, I provide readjusting means to supplement the primary control of the elements of combustion. For the air, such readjusting means comprises the damper 15 positioned at the inlet to the blower 288 by the pneumatic actuator 21. For the fuel the readjusting means comprises the regulating valve 13 positioned in the pipe 5 responsive to departure from desired relation of the measure of fuel flow and the measure of air flow.

The speed of the auxiliary turbine is regulated through varying the opening of steam admission valves 31 adapted to admit steam to the turbine 287. Such steam may be exhaust steam or extraction steam from the turbine 12, or high pressure steam direct from the vapor generator, or steam from any or a combination of sources. A pneumatic actuator 40 positions the valves 31 under the influence of an air loading pressure established by a standardizing relay 41 illustrated in detail at Fig. 6.

In order to regulate the liquid inflow (through variation in speed of the water pump) I preferably accomplish the regulation responsive to liquid inflow, vapor outflow, and the level of liquid in the separator.

As previously mentioned, the flow meter 25 is responsive to vapor outflow and is adapted to vertically position the stem of a pilot 26 to which a supply of compressed air may be available as indicated by the small arrow. Such a pilot valve is shown in detail at Fig. 4 and forms the subject matter of a patent to Clarence Johnson, No. 2,054,464 dated September 15, 1936.

Air under pressure is supplied to the interior of the casing 26 intermediate the pilot lands 44, which lands are so spaced along the stem as to coincide with narrow annular ports 45. When the pilot stem is axially moved in the casing so that the lands 44 are moved relative to the ports 45, then a definite loading pressure is available in the annular ports bearing a known relation to the amount of such movement. For example, if the pilot stem is moved upwardly there is available at the upper left-hand exit of the casing 26 a loading pressure increasing in definite relation to said movement, while if the pilot stem is moved downwardly there is available at the lower left-hand exit a pressure increasing definitely with such movement.

I indicate pipes or capillaries for transmitting such air loading pressures, throughout the drawings, by dotted lines to distinguish from electrical connections or other pipes or conduits. In Fig. 1 then, such a connection is illustrated at 28 for transmitting an air loading pressure bearing a known relation to rate of vapor outflow to the differential relay device 27. Such a differential relay is illustrated in detail at Fig. 5.

In similar manner the liquid level indicator 29 vertically positions the stem of a pilot 30 to establish at the relay 27 an air loading pressure representative of liquid level.

Referring to Fig. 5, the connection 28 leads to a chamber 50, separated by a diaphragm or movable partition 52 from a chamber 51 open to the atmosphere. The diaphragm 52 and loading spring 53 are both connected to a stem 54 to

which is also attached a diaphragm 55, separating the chambers 56, 57. Connection 46 leads to the chamber 56. A supply of air under pressure is available through the connection 58 to the chamber 57 under the control of a valve 59. Exhaust from the chamber 57 to the atmosphere is under the control of a valve 60. The stem 54 is adapted to position a valve actuator 61 to either admit air under pressure through the valve 59, thus increasing the pressure within the chamber 57, or to bleed air to the atmosphere through the valve 60 and thus decrease the pressure within the chamber 57. Pressure within the chamber 57 is transmitted through a connection 62 to a spring loaded diaphragm actuator for positioning the valve 17 in the suction line to the water pump.

Certain features of the differential relay 27 are disclosed and claimed in my Patent No. 2,098,913, dated November 9, 1937.

It will be observed that variations in the loading pressure effective through the connection 28, or that effective through the connection 46, will be effective to vary the air pressure within the chamber 57 and correspondingly effective upon the positioning of the valve 17.

The valve 17 acts as a variable orifice across which there will exist a pressure differential bearing a known relation to the rate of flow of liquid through the valve 17. Pressures on opposite sides of the valve are effective through the pipes 63, 64 respectively in chambers 65, 66 of the standardizing relay 41.

Referring now to Fig. 6 it will be observed that the standardizing relay 41 is to a certain extent similar to the relay 27, with the addition of a controllable bleed connection 67 between the chambers 56' and 57', certain features of which construction are disclosed and claimed in the patent to Harvard H. Gorrie, No. 2,098,914, dated November 9, 1937. A loading pressure established within chamber 57' is effective through a connection 68 upon the pneumatic actuator 40 for positioning the steam admission valve 31. In this instance the function of the controllable bleed connection 67 is to supplement the primary control of the pressure effective upon the actuator 40 with a secondary control, of the same or different magnitude, as a follow-up or supplemental action to prevent over-travel and hunting, and wherein the positioning of the actuator 40 will not necessarily be directly with the positioning of the valve 17.

In general the valve 17 is positioned responsive to vapor outflow and to liquid level within the separator and forms a variable orifice in the suction line to the water pump. The device 41 receiving the differential pressure across valve 17 positions the actuator 40 and the turbine valves 31 to control the speed of the water pump in such manner that the differential pressure across the valve 17 will be held constant regardless of the opening of the valve 17 and thus the liquid flow to the water pump is controlled proportional both to vapor outflow and to liquid level within the separator.

If vapor outflow increases, then the stem of the pilot 26 is raised proportionally, thus proportionally increasing the loading pressure effective through the connection 28, causing a downward movement of the stem 54 and a corresponding opening of the valve 59 to additionally admit air under pressure within the chamber 57, thus increasing the air loading pressure through the connection 62 upon the valve 17, and increase the opening of the valve to allow a greater flow of

water to the water pump commensurate with the increase in vapor outflow from the vapor generator.

Should the liquid level within the separator 232 tend to fall, the stem of the pilot 30 will be raised, thus increasing the loading pressure in the chamber 56, and in like manner further opening the valve 17 to increase the supply of liquid to the vapor generator.

It will then be observed that the valve 17 acts as a variable orifice positioned responsive to vapor outflow from the generator and liquid level in the separator, while the speed of the water pump is not only responsive to these two variables but additionally to the rate of flow of water to and through the pump. The actuator 40 varies the speed of the auxiliary turbine to vary the flow of water through the valve 17 to hold the pressure drop across the valve 17 constant. This, of course, means a constant water flow for every governor control valve position. It will be seen from this that the auxiliary set speed is regulated to maintain a definite water flow in accordance with the demand indicated by steam flow and water level.

Certain features of the control system in general are disclosed and claimed in my co-pending application, Serial No. 55,023, filed of even date herewith.

In Fig. 2 I illustrate a further embodiment of my invention. A turbine 69 is supplied with steam through a pipe 70 under the control of a diaphragm actuated valve 71. The turbine is adapted to drive a liquid pump 72 supplying liquid to a pipe 73, in which is located a hand throttle valve 74. The throttle valve 74 is to be adjusted as desired by hand either locally or remotely to control the amount of liquid discharged through the pipe 73. The system in general constitutes a control of the speed of the turbine 69 in accordance with and responsive to the flow through the pipe 73 and through the valve 74.

A standardizing relay 75 similar to the relay 41 is connected across the valve 74 by the pipes 76, 77 in such manner as to be responsive to the differential pressure existing across the valve 74. The valve 74 performs the function of a variable orifice and the relay 75 constitutes in effect a meter of the pressure differential across the variable orifice. An air loading pressure is established by the relay 75 in the line 78 effective upon the valve 71 for positioning the same.

When the valve 74 is opened or closed to a new position, the area for passage of fluid there-through correspondingly varies as does the differential pressure effective through the pipes 76, 77 upon the differential stabilizing relay 75. This relay is adjusted for a certain differential pressure, and when the existing differential pressure departs in either direction from the predetermined value, then the air loading pressure effective through the pipe 78 upon the valve 71 is varied, causing a change in the throttling position of the valve 71 and correspondingly a change in the rate of supply of steam to the turbine 69. The speed of the turbine 69 and of the pump 72 is thus varied in desired direction and amount until the flow of fluid through the valve 74, at its new opening position, creates a pressure differential across the pipes 76, 77 equal to, or proportionate to, the pressure differential which existed between these pipes at the previous degree of opening of the valve 74. Thus the control of the speed of the turbine 69 is in accordance with the output of the pump 72 and of the turbine 69.

It will be understood that by such a control system, all such variables as flow characteristics of the valve 71, of the admission nozzles, etc. of the turbine 69, changes in temperature, pressure, etc. of the steam admitted through the pipe 70, etc. as well as characteristics of the turbine and pump, are disregarded and the final result is a flow through the pipe 73 definitely in accordance with the valve stem position of the valve 74. This valve stem may then be accurately calibrated in terms of water flow versus valve stem travel and the relationship will hold true regardless of any of the variables before mentioned or others, which might otherwise affect the operation of the turbine and the pump.

In Fig. 3 I illustrate a still further embodiment of the invention, wherein an air fan 79 is driven by a steam turbine 80 under the control of an air-actuated mechanism 81. Air from the fan 79 passes through a conduit or duct 82 to a furnace 83 to provide the air to support combustion of fuel, such as fuel oil supplied through a pipe 84 to a burner 85. The system proportions the air to the fuel, in direct or graduated value as may be desired.

In the fuel oil supply line 84 is located an orifice or other differential producing restriction 86. A flow meter 87 is located to be sensitive to pressure differential across the orifice 86 and is of a type similar to the flow meter 14 previously referred to. The flow meter 87 is adapted to position a pilot 88 to establish an air loading pressure at the pneumatic actuator 89 for the positioning of the damper 90.

The damper or valve 90 is positioned across the duct 82 to provide a variable orifice for the measurement of the flow of air to the furnace. The pressure drop across the damper 90 is transmitted through the pipes 91, 92 to a stabilizing relay 93 which is of the type illustrated in Fig. 6. This stabilizing relay establishes a loading pressure effective upon the air actuator 81 for control of speed of the turbine 80.

In general the control of the supply of fuel oil through the conduit 84 may be by hand or from any variable in the operation of the furnace or other process. The flow is measured by the meter 87 which establishes a loading pressure to position the actuator 89 and the damper 90 (variable orifice). The pressure differential across the damper 90 establishes a loading pressure effective for control of the steam inlet valves of the turbine 80 to vary the speed of the turbine and of the fan 79 in direction and amount such as to maintain the pressure differential effective upon the relay 93 at a constant value. Thus for every value of fuel oil rate of flow there will be a definite position of the damper 90 and the speed of the turbine 80 will be automatically controlled to maintain the pressure differential across the damper 90 constant, and thus vary and control the flow of air to the furnace in desired proportion to the supply of fuel oil.

The lands of the pilot 88 may be so shaped that the flow of air will be in direct proportion to the flow of oil at all rates of operation or may increase with rate of fuel oil supply or decrease with the rate of fuel oil supply or as desired.

While I have chosen to illustrate and describe certain preferred embodiments of my invention it will be understood that I am not to be limited thereby, but only as to the claims in view of prior art.

What I claim as new, and desire to secure by Letters Patent of the United States, is:

1. In combination, a vapor generator, a heating furnace therefor, a turbine adapted to operate liquid and fuel and air supplying means for the vapor generator in unison, a regulating valve in the liquid supply line, means responsive to vapor outflow for positioning said valve, means sensitive to pressure differential across said valve, and speed governing mechanism for the turbine under the control of said last named means.

2. In combination, a vapor generator of the drumless forced flow type having a separator between the generating and superheating portions of the fluid flow path, liquid supply means for the generator, and means responsive to vapor outflow and liquid inflow and liquid level in said separator for effecting regulation of said liquid supply means.

3. In combination, a vapor generator of the drumless forced flow type having a separator between the generating and superheating portions of the fluid flow path, a turbine adapted to operate liquid and fuel and air supplying means for the vapor generator in unison, a regulating valve in the liquid supply line, means responsive to vapor outflow and to level in the separator for positioning said valve, means sensitive to pressure differential across said valve, and speed governing mechanism for the turbine under the control of said last named means.

4. In combination, a vapor generator of the drumless forced flow type having a separator between the generating and superheating portions of the fluid flow path, means for supplying liquid and the elements of combustion to said generator, and means responsive to liquid inflow and liquid level in said separator for effecting regulation of said first named means.

5. In combination, a vapor generator of the drumless forced flow type having a separator between the generating and superheating portions of the fluid flow path, liquid supply means for the generator, and means responsive to liquid inflow and liquid level in said separator for effecting regulation of said liquid supply.

6. In combination, a vapor generator of the drumless forced flow type having a separator between the generating and superheating portions of the fluid flow path, a turbine adapted to operate liquid and fuel and air supplying means for the vapor generator in unison, a flow regulating valve in the liquid supply line, and means responsive to vapor outflow and to level in the separator for positioning said valve.

7. In combination, a vapor generator of the drumless forced flow type having a separator between the generating and superheating portions of the fluid flow path, a turbine adapted to operate liquid and fuel and air supplying means for the vapor generator in unison, a flow regulating valve in the liquid supply line, means responsive to vapor outflow and to level in the separator for positioning said valve, means sensitive to rate of liquid flow through said valve, and speed governing mechanism for the turbine under the control of said last named means.

8. In combination, a vapor generator, a heating furnace therefor, a turbine adapted to operate liquid and fuel and air supplying means for the vapor generator in unison, a regulating valve in the liquid supply line, means responsive to load on the vapor generator for positioning said valve, means sensitive to pressure differential across said valve, and speed governing mechanism for the turbine under the control of said last named means.

9. In combination, a vapor generator, a heating furnace therefor, a turbine adapted to operate liquid and fuel and air supplying means for the vapor generator in unison, a regulating valve in the liquid supply line, means responsive to a variable in the operation of the vapor generator for positioning said valve, means sensitive to pressure differential across said valve, and speed governing mechanism for the turbine under the control of said last named means.

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